Application of aircraft lightning protection to radar stations

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Abstract: Near an antenna (radar or radio frequencies), set-up of a standard metallic lightning protection system may create troubles due to its metallic frame which may disturb the field emitted or received by the antenna. To solve this problem a new lightning protection system has been developed which is "transparent" to electromagnetic waves. This new lightning protection system has been tested thoroughfully with high voltage impulse and the high energy lightning strike used by the aircraft industry. Testing performed are described. Area protected by this system is the same than the one given by a metallic lightning rod and all the standard rules have to be fulfilled.

Keywords: Radar, lightning protection, lightning rod

1. Introduction

Near an antenna (radar, radio frequencies …), set-up of a standard metallic lightning protection system may create troubles due to its metallic frame which may disturb the field emitted or received by the antenna. In most of the cases, this disturbance is negligible if the lightning protection systems is far enough from the antenna. It is not always the case for some radar antennas with narrow angle detection for which the sole presence of the down-conductor (which becomes even more obvious if the conductor is supported by a mast or a pole) brings enough disturbance to prevent the user to install lightning protection means. But experience shows very clearly that lightning impact to radar exists and are creating significant damages. So a solution was needed.

Figure 1 : lightning diverter strip

To solve this problem a new lightning protection system has been developed which is "transparent" to electromagnetic waves. This is based on the technology used on aircraft nose to protect the radome where the radar is located. It is made of a fiber glass rod on which is deposed a "sparkover" band (also called lightning diverter strips in aircraft industry, see figure 1) which is a substrate with some metallic elements of triangular shape. This is a non conductive band when the electric field is low but when the field is high the arc created at the surface between the metallic elements allow the connection from top to bottom to create a conductive path and when it is stroke this band allows the circulation of the current on the surface. Based on the fact current is circulating only on the surface, it is able to withstand high stress and testing have shown that it is able to withstand current up to 200 kA without damaging the band.
This new lightning protection system has been tested thoroughfully especially in the high voltage laboratory of CEAT (Centre d'Études Aéronautiques de Toulouse, laboratory making test especially for the aircraft industry namely in our case, high voltage impulse and the high energy lightning strike used by the aircraft industry), which led to a product which is now installed on all the "TACAN" antennas for the French air force. In addition, testing to show the transparency of this rod to the radar beam as well as EMC testing to check the electronic immunity have been performed. As a matter of fact, the rod by itself is not enough and LEMP rules had to be applied.

Area protected by this system is of course the same than the one given by a metallic lightning rod of same height and all the standard rules have to be observed. Particular care is important for connection at bottom of the rod to avoid damaging the strip and also allow good equipotentiality.

2. First developments

The simplest idea was to apply the lightning diverters strip directly on the external radome surface. Such an idea has been applied with 4 strips positioned at equal distance on the surface. First of all, tests have been made in order to demonstrate that these strips didn't perturbed the radar frequencies. The emitting characteristics of the radar have been checked without the strips and compared to the case with strips. No noticeable changes have been recorded between the two cases. Then operation characteristics have been checked with a receiver located 50 m away from the radar and with another receiver (airplane type) located 150 m away. In any direction, the protected radar has passed successfully the test.

After having demonstrated that the strips didn't interfere with the radar in the needed frequency range it was, of course, necessary to check the behaviour of such strips in case of lightning conditions.

A 5 MV Marx generator was used to energized an electrode which was located 2,5 m above the reference plane of the antenna. The radar antenna was a dummy one with equivalent shape and equipped with measuring instruments. For this test, 6 strips where equally positioned on the surface of the antenna like before. Each strips is connected to a down conductor also connected to the frame of the antenna. The position of the electrode was changed in the test in order to find the more sever case. In each test, at least one strip connected the downward leader.

Figure 2 : testing of the strips directly on the radome

However, the main conclusion of these test is that the discharge is not following completely the strips path due to the big metallic mass of the antenna, its structure and the short distance between diverters strips and equipments. So a mechanical modification of the antenna was needed to apply this solution in order to ensure that at the place where the lightning discharge move from the strip to the structure there is no puncture. In addition, lightning current circulating so close to sensitive electronic could be a problem. Furthermore, in case of damage of the strips due to too high currents, the antenna should be removed for maintenance. For all these reasons, another solution had to be developed.

3. "Transrad" lightning rod

A special lightning rod has then been developed called "transrad" for "transparent to radar frequency".

The lightning diverters strips of the same type than before are stuck to a fibre glass rod. 4 rods are located around the antenna at 20 cm from it. They are connected to copper downconductors connected to the generator ground and to the antenna frame.

Once again the tests are first performed with a 5 MV generator and the electrode is located at various positions in order to check the efficiency of the rods. The electrode is first at 3,5 m above the antenna reference plane when the rods are located at 2 m above the same plane.

6 tests were performed which all led to connection to the rods.

3 more test were performed with the electrode being at 2 m (same height than the rod). Once again, all connected to the rods.

After these tests, the height of the rods have been changed, the electrode being always at 3,5 m. Rod heights of 1,7 and 1,3 m have been investigated and all led to connection to the rods. In spite of this, 1,7 m was considered as being the best height, especially to compensate a possible destruction of one of the strips.

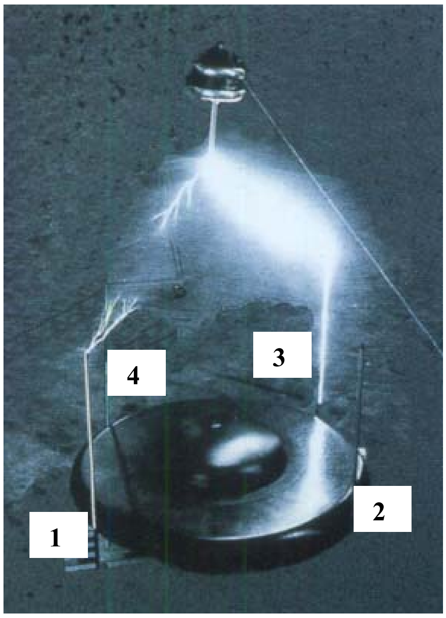

Figure 2 : testing at the high voltage laboratory. In that test transrad rod n°3 is struck

4. Lightning current tests

These tests have been performed using the aeronautic lightning wave shape A+B+C+D.

A : I : 200 kA, W/R : 2.10^6 A²s, T < 500 µs

B : I : 2 kA, Q : 10 C

C : I : 200-800 A, Q : 200 C

D : I : 100 kA, W/R : 0,25 10^6 A²s, T < 500 µs

The tests are performed using square samples (400 x 400 mm) being made of the same material than the radome. A lightning diverter strips is stuck on the sample.

An electrode located to the generator is situated 1,5 cm above the sample.

The tests shown that the current is circulating along the strips without damaging the sample. However, a second shot on the same sample led to the destruction of the strips.

5. LEMP tests

The rods were found working satisfactorily but of course their ability to connect lightning discharge also means that lightning current will circulate close to the sensitive electronic equipment of the antenna.

To check this influence test have been performed. Electric and magnetic fields as well as voltage and currents have been measured at various places.

The 5 MV generator was one more time use for these tests and the current injected in one of the rods was around 5 kA. Values of voltage as high as 840 volts where found on a 10 kΩ resistance. It was then decided to study a protection scheme based on all the measurements made.

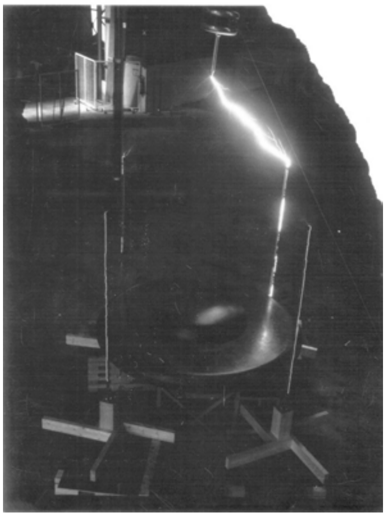

Figure 3 : LEMP tests. We can observe the sparkover along the lightning diverter strips

This protection scheme included :

A better shielding of some cables

A better shielding of some sub-systems

A better equipotentiality between elements

A common 0 V reference

Some SPDs located on cables connected to the ground.

To prove the efficiency of these actions, another set of tests has been performed. 70 shots at 50 kA have been carried out (direct injection on a transrad rod) with the same measurement than above on a true antenna as well as some tests to check after each shot that the antenna was still performing well.

After each test, it has been demonstrated that the antenna still behave correctly. Only an overvoltage of 6 V on a 5V circuit led to temporary malfunction in a few cases but which didn't change the overall behaviour of the antenna.

Figure 3 : Testing in field

Finally other tests have been performed to demonstrate that the protection scheme was not modifying the antenna characteristics. These final tests where made in field on a true antenna.

6. Conclusions

Some antennas cannot be protected against lightning by metallic lightning rods. In such case, specific rods can be used which are made of lightning diverters strips stuck to a fibre glass rod. The configuration used is made of 4 of such rods located at 20 cm from the edge of the radome and located at equal distance from each other. Tests have been performed in a high voltage laboratory to check ability of these rods to capture the lightning. After these tests, lightning current test and LEMP tests have been performed to check the global efficiency. The complete protection scheme including transrad lightning rods, equipotentiality, shielding and surge protection has been proven to be working satisfactorily. Experience in field since almost 10 years is good. Many lightning strikes have been collected by the transrad rods.

New tests [1] performed recently on new lightning diverters shows that solid strips are even behaving better than the one used in our study (segmented strips) especially in case of high humidity. The behaviour of these new strips need to be investigated for transrard applications.

7. References

[1] P. Laroche et al. "new investigations of the mechanism of lightning strike to radomes " ICOLSE September 11-13 2001